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Assessing the Effectiveness of Green Infrastructure

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Aerial photo of Kingston's Uptown Parking lot and green infrastructure practices (Shawn Willis, Notice Pictures)

Abstract
Although green infrastructure has become increasingly accepted as a technique to reduce runoff and improve water quality, questions remain about its effectiveness in the field. Water quantity in particular has implications for localized and riverine flooding, managing extreme storms, reducing combined sewer overflows, and improving stream ecology/geomorphology that may be harmed by flashy runoff patterns. This study will focus on a water budget for two municipal parking lots in Kingston, NY. In fall 2016, these parking lots were redone with several green infrastructure practices (bioretention areas, pervious pavement, and dry wells), with the goal of having no runoff leave the site. This study has three components: a quantitative assessment of runoff reduction in the bioretention areas and dry wells, a qualitative assessment of design features of the overall site, and a review of the historical context of restoration within the Tannery Brook watershed.

Three Summary Points of Interest

- **The bioretention areas and dry wells appear to reduce runoff very quickly, particularly the dry wells.**
- **After construction, the City of Kingston has made several changes to improve the design of the parking lots, with implications for the green infrastructure practices.**
- **The history of water management in the Tannery Brook watershed provides a unique case study and context for restoration practices such as green infrastructure.**

Keywords: green infrastructure, stormwater management, urban runoff, urban stream

Introduction

Although green infrastructure has become increasingly accepted as a technique to reduce runoff and improve water quality, questions remain about its effectiveness in the field. As stormwater practices are increasingly constructed in in previously developed areas as retrofits, it is important to understand how these practices function. Better quantifying runoff reduction can also help communities understand expectations for stormwater practices, and help overcome barriers to more programmatic implementation (Green Nylen & Kiparsky 2015). Water quantity in particular has implications for localized and riverine flooding, managing extreme storms, reducing combined sewer overflows, and improving stream ecology/geomorphology that may be harmed by flashy runoff patterns.

The Hudson River Estuary Action Agenda 2015-2020 is a conservation and restoration blueprint for the Hudson River estuary ecosystem. Its first long-range target for Clean Water states: "Water quality in the estuary, its tributaries, and watershed is maintained and improved to support municipal drinking water supplies, swimming and other types of water-based recreation, as well as aquatic life" (NYS DEC Hudson River Estuary Program 2015). The Action Agenda also includes the 2020 outcome that: "Green infrastructure is used where feasible and cost effective to achieve more pollution reduction in the estuary, and the effectiveness of green infrastructure as a tool for improving water quality is better understood" (NYS DEC Hudson River Estuary Program 2015).

This research project will assess the effectiveness of green infrastructure and local conditions at two municipal parking lots in Kingston, NY to better understand how these practices can be used to improve clean water in the Hudson River estuary watershed.

Site Background

The City of Kingston is located between the Rondout Creek and the Lower Esopus Creek in Ulster County, New York in the mid-Hudson Valley. As July 2016, Kingston's population was estimated to be 23,210 people (US Census 2017).

In 2007, the New York State Department of Environmental Conservation (NYS DEC) listed the Lower Esopus Creek (from the confluence with the Tannery Brook in Kingston to its mouth in Saugerties) as having "Minor Impacts." This segment is Class B (best use is swimming or other contact recreation), but various uses, including public bathing, aquatic life, and recreation, were considered stressed. Urban/storm runoff was also identified as a known source of pollution, particularly for phosphorus (NYS DEC 2007).

In 2012, the United States Environmental Protection Agency (US EPA) appended this segment ("Esopus Creek, Lower, Main Stem") along with the upstream segment ("Esopus Creek, Middle, Main Stem") to the Section 303(d) List of impaired waterbodies. The specific cause/pollutant was turbidity, and suspected source was stream erosion (NYS DEC 2016).

The City of Kingston applied to the NYS DEC's Water Quality Improvement Program grants to improve stormwater management at three municipal parking lots, with a primary goal of the project to reduce sediment loading into the Lower Esopus Creek. The grant application included green infrastructure stormwater projects in the two municipal parking lots on North Front Street (Kingston Uptown Parking Lots) and one parking lot in the Midtown neighborhood.

NYS DEC awarded the $365,831 grant in 2013, and the City of Kingston contracted with engineering firm Barton & Loguidice, D.P.C (based in Albany, NY) to design and manage the project. Barton & Loguidice subcontracted for general construction (including removing existing pavement and stormwater structures and installing new pavement, striping, green infrastructure, and landscaping).

This study focuses on the two Kingston Uptown Parking Lots on North Front Street in the Uptown neighborhood/Stockade District. They are located directly across the street from each other, near the intersection with Crown Street. Although this area has separated storm sewers, much of the City of Kingston is served by a combined sewer system that discharges into the Rondout Creek.

This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the NYS Environmental Protection Fund

Results & Discussion

Barton & Loguidice completed engineering designs for the parking lots and green infrastructure in August 2015. Since the project was considered a retrofit, practices were not required to meet the standards in the NYS Stormwater Management Design Manual. However, the designed practices were representative of good design practice.

As part of the design, Barton & Loguidice used HydroCAD to calculate runoff reduction for each practice (2-, 10-, and 100-year storms). The City of Kingston also calculated pollutant load reductions using EPA Region 5 Model (STEPL, or the Spreadsheet Tool for Estimating Pollutant Load). This model estimated that bioretention/infiltration practices at the two parking lots would reduce 0.8 tons/year of sediment, 3.4 pounds/year of phosphorus, and 17.4 pounds/year of nitrogen to the Esopus Creek (City of Kingston 2013). These calculations were updated in 2015 with the microcatchments for each parking lot/practice.

Construction on the South lot began on August 1, 2016, and was completed by September 12, 2016. Construction on the North lot began on September 12, 2016, and completed by October 17, 2016. Bioretention areas in both lots were planted on October 13, 2016.

The South lot has three bioretention areas (two with underdrains, one without), three dry wells, and one section of pervious pavers. Although there is another strip of pervious pavers between parking lanes on the west side of the lot, this section appears to be crowned, and does not seem to infiltrate runoff.

The North lot has two bioretention areas (one with underdrain, one without), two dry wells, and two sections of pervious pavers.

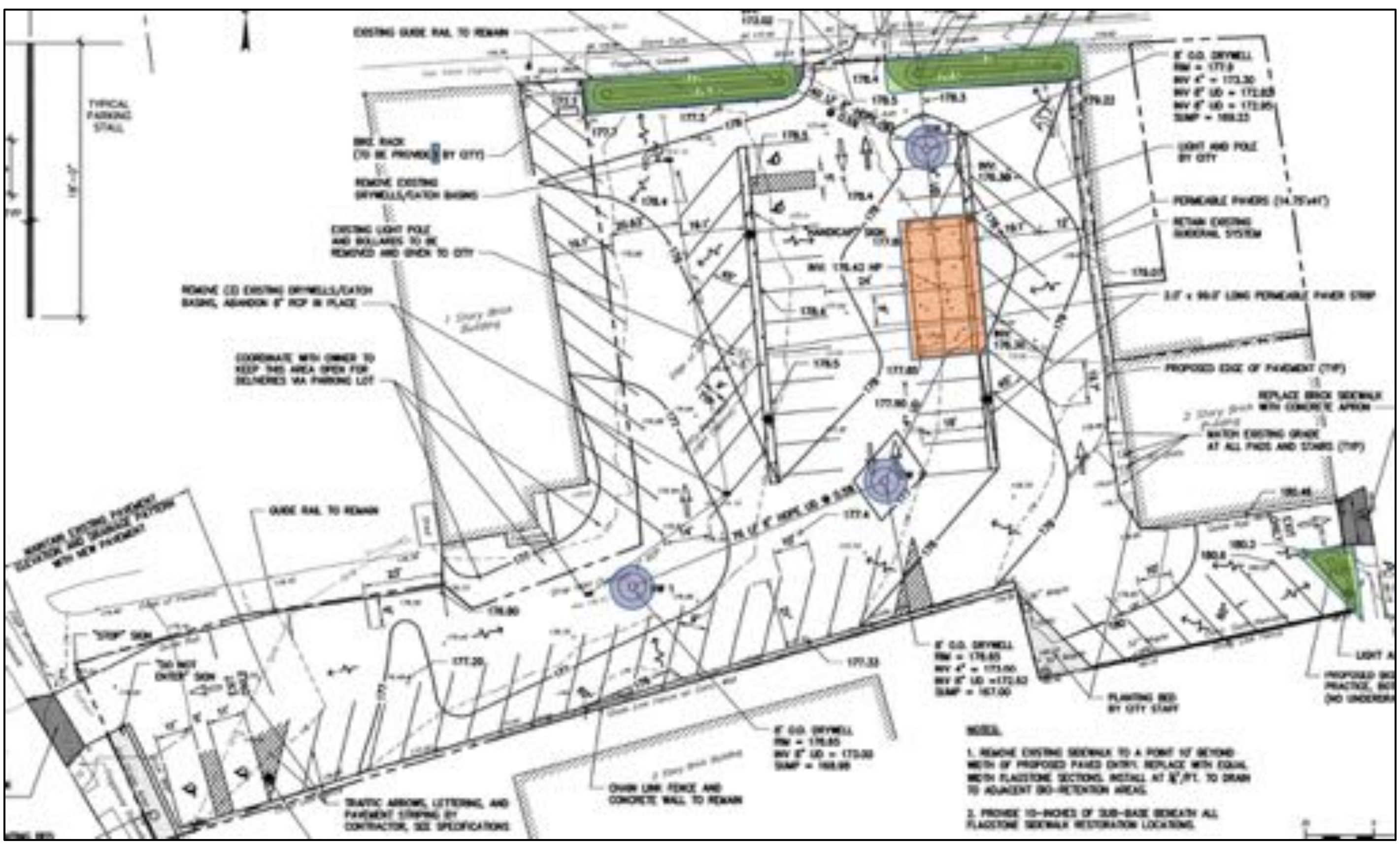

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Figure 1: Engineering plans for the South lot, with bioretention areas (green), pervious pavers (orange), and dry wells (purple) highlighted (Barton & Loguidice 2015).

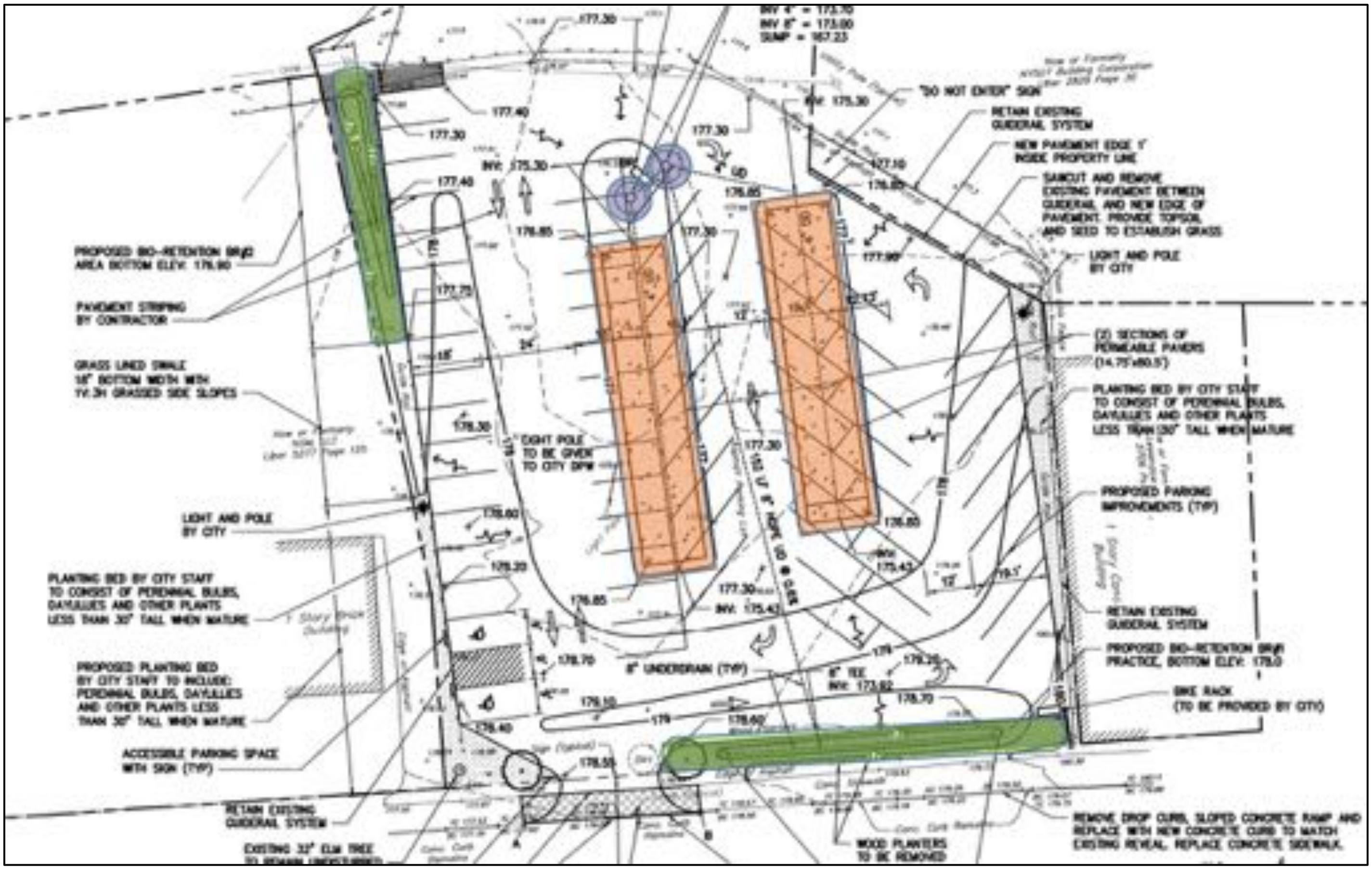

Figure 2: Engineering plans for the North lot, with bioretention areas (green), pervious pavers (orange), and dry wells (purple) highlighted (Barton & Loguidice 2015).

Quantitative Assessment

Onset HOBO pressure transducers were installed in the dry wells on November 22, 2016 and in the bioretention areas on November 23, 2016. In each of the five dry wells, a 1" perforated PVC pipe was installed to house the HOBO. In each of the two bioretention areas without underdrains, a 1" perforated PVC pipe was installed and buried 3 feet under the surface to house the HOBO. In each of the three bioretention areas with underdrains, the HOBOs were placed within the underdrain at the overflow structure. An extra transducer to measure barometric pressure was hung suspended within the overflow structure in Bioretention Area North 1, and these readings were used to convert pressure into water level in each of the green infrastructure practices.

The HOBOs were programmed to log pressure and temperature every minute. This information is supplemented by rainfall data. An Onset rain gage was installed at the site on May 5, 2017.

All of the practices with HOBOs appear to reduce runoff very quickly. There are clear hydrographs when water ponds in the practice, particularly in the two bioretention areas without underdrains, but water appears to be infiltrating very rapidly in all of the practices. Observations will continue through 2017 to gain more insight into performance during the growing season and in more intense rain storms.

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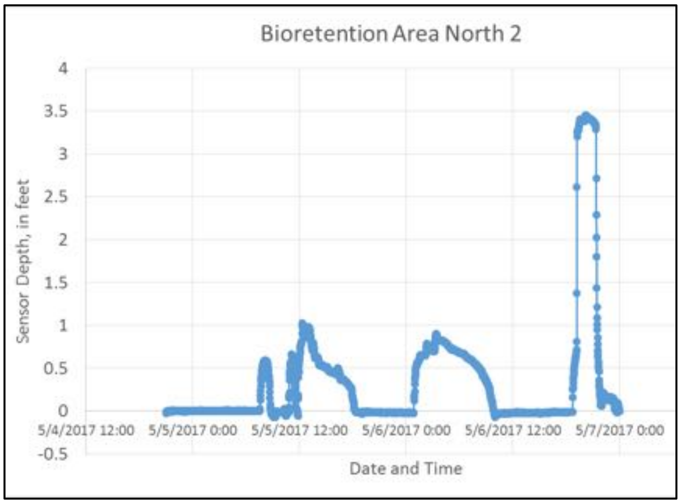

Figure 3: Example of a hydrograph from Bioretention Area North 2, which does not have an underdrain, between May 5 and May 7. Values are recorded every minute, and converted from pressure to sensor depth by HOBOWare software based on barometric pressure.

Qualitative Assessment

Frequent site visits (at least every two weeks) and observations on adaptive management can provide insight into how the parking lots function over time. Detailed case studies such as this can provide critical information to inform design standards, management, and maintenance. Although this site is not within the combined sewer system drainage area, much of the City of Kingston is. Similar practices could be implemented elsewhere in Kingston to reduce flooding or combined sewer overflows. This information can also be useful for other urban areas within the Hudson River estuary watershed.

The City of Kingston has had to make several changes to improve the design of the parking lots, which have implications for the stormwater practices and their function. These have included regrading around two of the dry wells (Dry Well South 1 and 2), installing fences to prevent cars from driving through the bioretention areas, and creating walkways alongside the bioretention areas for pedestrians to cross from the parking lot to the business area (Bioretention Areas South 1 and 2, Bioretention Area North 1).

Figure 4: Series of photos showing the progression of an informal walkway to a formal walkway through Bioretention Area South 1. From top to bottom, photos were taken on 1/1/17, 1/6/17 when gravel was installed, and 7/14/17 when block pavers were installed. This area was originally part of the stormwater practice, and the walkway reduces its designed storage capacity (photos by E. Vail).

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Historical Context: Tannery Brook Watershed

Topographically, the two parking lots should drain to the Tannery Brook; however, due to many management decisions over time, the Tannery Brook has been buried and natural flow paths have been substantially altered. The Tannery Brook's history of management dates from colonial settlement (1650s) through today. This small stream has provided numerous ecosystem services over time, including a source of water for breweries, clay for bricks, industrial mill power, recreation, and a conduit for waste. This history can provide context for restoration practices like green infrastructure or stream daylighting to improve water quality or flooding.

Methods for understanding the Tannery Brook's history include reviewing books on the history of Kingston, maps (dating as early as 1870), engineering plans and reports, newspaper articles (dating as early as 1889), photos, postcards, and personal communications with experts on local history.

Figure 5: 1899 Sanborne map showing the Tannery Brook's path and its confluence with Main Street Brook, its largest tributary. Maps like this one reveal the stream's historic path, in addition to shedding light on the relationship of the city with the Tannery Brook.

Policy Implications
Understanding the effectiveness of green infrastructure practices can help municipalities and regulators implement practices more strategically. Quantifying runoff reduction, for example, can give us a better idea of how to give "credit" for implementing certain practices. This detailed case study allows us to share valuable lessons learned about implementing green infrastructure retrofits in an urban area. The City of Kingston can learn for future projects, and other communities can also benefit.

Outreach Comments
Throughout the project, I've been working closely with the City of Kingston's Engineering Department, and also communicating with the City's environmental education and Department of Public Works staff.

I presented this work to Kingston's Climate Smart Commission, which also includes volunteers that are on Kingston's Conservation Advisory Council, at their March meeting (3/30/17). I also presented this work to Hudson River Estuary Program staff at the January staff meeting.

I plan to continue outreach to relevant stakeholders, including City of Kingston staff, Ulster County staff, as well as members of Friends of Historic Kingston and other local history projects.

Student Training
Graduate student training on various methods and HOBOware software.

Publications/Presentations
Presentation to City of Kingston Climate Smart Commission. "Green Infrastructure Research: Kingston Uptown Parking Lots." March 30, 2017.

Additional final reports related to water resource research are available at
http://wri.cals.cornell.edu/news/research-reports

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Sanborne Fire Insurance Maps. 1899. “City of Kingston Fire Insurance Maps: Sheet 2.”

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